The earth roadway to be improved shall first be cleared of all vegetable and other foreign materials and shall then be crowned with a road grader, or by hand, to the proper line and grade, filling in all low places with suitable material. It shall then be plowed to a depth of not less than eight inches, after which a disc-harrow shall be run over the surface of the plowed roadway in order that all lumpy material shall be disintegrated. The road shall then be carefully graded to the required cross section, after which there shall be distributed one gallon of hot asphaltic oil to the square yard of pavement. The sheep's foot or tamping roller shall then be used until its teeth refuse to penetrate into the soil for a distance of more than one inch. The material shall then again be lightly harrowed and an application of hot asphaltic oil, at the rate of not more than one-half gallon to the square yard, shall be applied, and the surface shall then be lightly harrowed, after which the tamping roller shall be again used until the teeth refuse to penetrate. The surface shall then be covered with a coating of stone chips or sand and rolled with light circular roller.

Other experiments with the same or allied processes were made in the east during the ensuing year with no better results, and in so far as this type of construction is concerned, it has been virtually abandoned outside of California.

Various states and municipalities then attempted to improve on the water-bound macadam and its filler of stone chips by substituting heavy asphaltic or semi-asphaltic oil, by means of what is termed the penetration or grouting method. The initial process relating to the preparation of the base and first course of stone was substantially the same as in the preparation of the water-bound type of macadam. The second course, generally composed of what is known as inch and a half stone, was then spread upon the base course and rolled with a 10-ton roller to an average thickness of about four inches. An application of asphaltic oil, heated to a temperature of approximately 300° F., was applied, at the rate of one and one-half gallons per square yard, by means of pouring pots or sprinkling wagons and immediately thereafter a coating of stone chips was applied and the surface was then again carefully rolled with a steam roller. Immediately after this rolling another application of hot oil was made at the rate of approximately one-half gallon to the square yard, and another course of stone chips applied, after which the surface was again rolled, and after a short period of time, ranging from 3 to 24 hours, the road was opened to traffic.

The success of this type of pavement is somewhat problematical, and has been abandoned in many places. The States of New York and New Jersey spent many millions of dollars in this type of road construction during the seasons of 1910-1911, but during the season of 1912 the use of this type of construction was almost entirely abandoned. In order to make a success of this type of construction it has been found necessary to have almost ideal climatic conditions. A working temperature of over 55° F. has been found necessary because in a lower temperature the stone becomes so cold that it immediately chills the asphaltum when applied and prevents it from thoroughly penetrating the voids in the mass; an unstaple top surface coat is thus formed with an under strata which is poorly consolidated Traffic soon finds the weak spots in this pavement, with the result that ravelling soon begins and the complete disintegration of the pavement is only a matter of a short time. In order to secure even fair results from penetration work the following conditions are absolutely necessary: An asphaltic oil of approximately 18 Beaume gravity at 77° F. A flash point of not less than 400° F. A fixed carbon total of not more than 6%. A bitumen content of not less than 99%, and a paraffin scale residue of not more than 3%. This material should be heated and applied at a temperature of not less than 300, or more than 350° F. The temperature of the air should not be less than 60° F. The mineral aggregate should be bone dry and the asphaltic oil should be applied to the surface by means of sprinkling appliances containing an exact quantity of the material; templates, or other means of determining the exact quantity of oil to be applied per square yard of roadway should be laid on the prepared road surface, in order that an even distribution of the oil may be secured.

Power sprinkling devices employing compressed air as an atomizer have been used with fair results, but the continued decrease of this method of construction in favor of some method of the mechanical mixing of the cementing medium and the mineral aggregate, is proof evident that at its best the penetration system is only a step in the right direction from the water-bound macadam era to the present era of mixed bituminous surfaces.

Bituminous Macadam.—This type of pavement has been largely adopted for use on main highways and also on the principal streets of some smaller towns. A specification of this type of pavement as prepared by the State Highway Department of Pennsylvania is submitted herewith.

"After completion of the bottom course, telford or macadam, the bituminous macadam course is to be placed thereon. It shall consist of a mixture of bituminous material and good hard stone acceptable to the State Highway Department, trap rock preferred. When trap rock is used the stone shall be of such size as will pass through a two-inch ring and be rejected by a half-inch ring, and shall be entirely free from dust. When limestone is used it shall be of such size as shall pass through a three-inch ring and be rejected by a one-inch ring. When asphalt is used it shall contain not less than 90% bitumen and shall be heated to a temperature of 350 to 400° F. When tar is used it shall be heated to a temperature of 270 to 325° F. The bituminous material shall be mixed with the stone in a mechanical mixer and then spread on the telford foundation to a depth of five inches in the centre for a width of six feet, and to a depth of four inches on the sides, loose measurements, and thoroughly rolled and compacted. One and five-tenths gallons to two gallons of bituminous material per square yard of road surface will be required to make the mixture. The contractor shall, upon the direction of the engineer in charge, heat the stone to a temperature of 250 to 300° F. before mixing the compound. After the above-mentioned course has been thoroughly rolled in place and compacted with a ten-ton roller, to the satisfaction of the engineer or inspector in charge, and the surface swept clean, the surface shall be painted with the neat bituminous material, using five-tenths of a gallon per square yard of road surface, unless otherwise directed by the engineer. Immediately following the flush coat or painting there shall be applied a coating of clean rock screenings, ¼ to ¾ inch in diameter, of the same material as has been used in the four-inch course, to a depth of ½ inch and rolled into the voids in the surface. Should the bituminous binder appear on the surface after rolling, enough additional rock screenings must be applied to take up the surplus material."